LAWRENCE
LIVERMORE
NATIONAL
LABORATORY

LLNL-TR-675623

Measurement of the ambient gamma dose equivalent and kerma from the small 252Cf source at 1 meter and the small 60Co source at 2 meters

W. F. Carl

July 30, 2015

Disclaimer

This work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.

Disclaimer

This work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.

Measurement of the ambient gamma dose equivalent and kerma from the small ^{252}Cf source at 1 meter and the small ^{60}Co source at 2 meters

William Carl, LLNL

1. Background

NASA Langley Research Center requested a measurement and determination of the ambient gamma dose equivalent rate and kerma at 100 cm from the ^{252}Cf source (model NS-120, LLNL RCL # 7001677, referred to as the Small ^{252}Cf source) and determination of the ambient gamma dose equivalent rate and kerma at 200 cm from the ^{60}Co source (RCL # 7001674, S/N-400608, referred to as the Small ^{60}Co source) for the Radiation Budget Instrument Experiment (Rad-X).

2. Sources

a. Neutron source

The Small ^{252}Cf source was manufactured and calibrated by ORNL's Chemical Technology Division. ORNL stated its activity as 1.682 mg on 3/31/1985. ORNL reported its isotopic composition on September 5, 1984 with ±3% uncertainty as

^{249}Cf - 5.48 atom %
^{250}Cf - 11.05 atom %
^{251}Cf - 3.43 atom %
^{252}Cf - 80.05 atom %
^{253}Cf - <0.004 atom %
^{254}Cf - <0.004 atom %

The ^{252}Cf content was reported by ORNL to be 1.887 mg on 9/5/1984. ORNL calculated the ^{252}Cf content on 3/31/1985 as 1.682 mg. As per ORNL the californium in this neutron source is believed to be in the form of the oxysulfate, $Cf_2O_2SO_4$, as a result of the thermal decomposition of the Dowex-50 resin on which the californium was sorbed.

b. ^{60}Co source

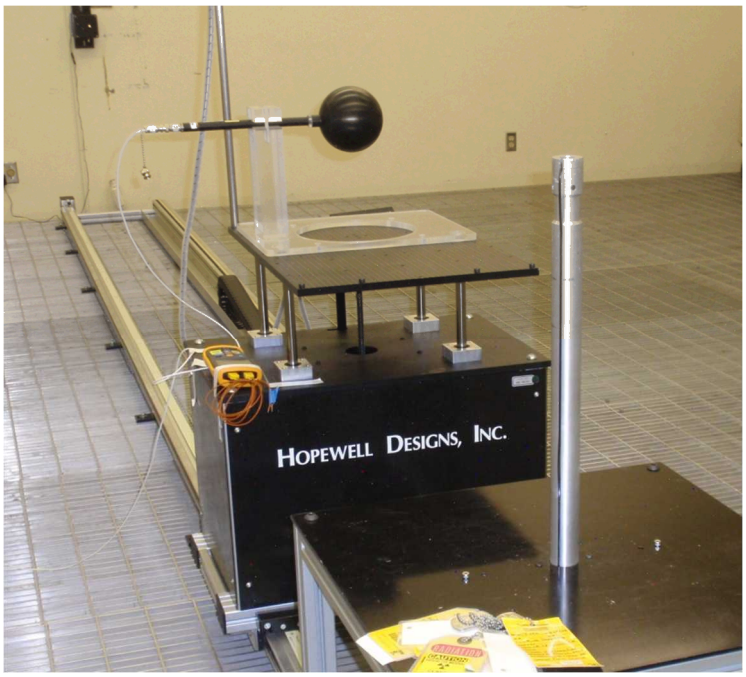
S/N – 400608. There is no documentation available regarding the history of this source.

3. Equipment and experimental set up

An Exradin A6 ion chamber with Shonka air-equivalent plastic walls [3] in combination with a Supermax electrometer were used to measure the exposure rate and free-in-air kerma rate of the two sources at the requested distances.

The sources were pneumatically positioned by the Hopewell N40 Irradiator System located in the center of LLNL's Radiation Calibration Laboratory cell A; Low Scatter Cell. Cell A has dimensions 12.2 m x 9.1 m and 6 m height. Source exposure times were controlled by the Hopewell Irradiator System, the discrete measurement time was controlled by the Supermax Electrometer. Each measurement was begun after the ion chamber stabilized to the source exposure. The measurement times used were 120 seconds for the ^{60}Co source and increased to 300 seconds for the ^{252}Cf source due to the lower signal from that source. The electrometer was zeroed between measurements to minimize the effect of leakage current on the results. The source was exposed and the ion chamber was allowed to stabilize prior to initiating the measurement. The distance used, measured from the center of the source to the center of the ion chamber, was 100 cm for the small ^{252}Cf source and 200 cm for the small ^{60}Co source. The distance was controlled by the Hopewell Irradiator System software and the linear positioning system (LPS), with accuracy ±0.1 cm, in the North direction from the sources. The alignment of the ion chamber was verified by laser beam and the ion chamber fixture, Figure 1 below.

Figure 1: Ion Chamber and Source Orientation



Measuring and Test Equipment:

- Exradin A6, 800 cc ion chamber, RCL #7002459, S/N-P080721, NIST traceable calibration on 10/29/2014. Calibration uncertainty: 1.6%.
- Standard Imaging Supermax Electrometer, RCL #7002458, S/N-P082122, NIST traceable calibration on 10/28/2014. Calibration uncertainty: 0.2%.
- Fluke 52 II Thermometer, RCL #7001415, S/N 14400098, NIST traceable calibration on 10/13/2014. Calibration uncertainty: 0.8%.

- Setra Datum 2000 Barometric Sensor with model 276, RCL #7001432, S/N-3634501, NIST traceable calibration on 11/12/2014. Calibration uncertainty: 0.006%.

Coefficients:

- A6 ion chamber exposure calibration coefficient for ^{137}Cs = 4.390 E6 R/C;
- A6 ion chamber air kerma calibration coefficient for ^{137}Cs = 3.854 E4 Gy/C.
- Gamma ambient dose equivalent conversion coefficient = 1.20 for 0.662 MeV and = 1.16 for 1.25 MeV. [1]

4. Measurement results

The ambient background radiation measured in cell A was low, but not sufficiently low to be excluded from the measurements. The measurements were performed on June 03, 2015. Temperature and barometric pressure readings were obtained along with the ion chamber measurements. The ion chamber measurement results were corrected for temperature and pressure deviation from calibration conditions. The ^{60}Co source measurements were adjusted +1% to account for the slight energy dependence of the ion chamber. [2] This is further described in the following note.

Note: The Exradin A6 ion chamber was calibrated to ^{137}Cs by the University of Wisconsin Accredited Calibration Laboratory. The energy response of the A6 ion chamber to energies of 100 keV and higher is nearly linear and energy response correction can normally be ignored. For the measurement with the ^{60}Co source, a minor correction, addition of 1%, was made to account for the slight energy dependence of the ion chamber to the higher energy photons as compared to ^{137}Cs [2]. The correction was included in the measurement results shown in Table 2; column labelled: “Corrected Reading”, for the ^{60}Co source only.

Table 1. Summary: Gamma Exposure, Kerma, and Dose Equivalent Rates

Source	Distance (cm)	Exposure Rate (R/hr)	Kerma Rate (rad/hr)	H*(10) Rate (rem/hr)
^{252}Cf	100	2.998E-04	2.632E-04	3.158E-04
^{60}Co	200	3.678E-03	3.229E-03	3.745E-03

Table 2. Gamma Measurement Results:

Source	Distance from source (cm)	Measured Charge (pC)	Measurement Time (sec)	Temp (°C)	Pressure (mmHg)	Reading / Hour (nC/hr)	Temp-Press Correction	Corrected Reading (nC/hr)	Bkgd Corrected Reading (nC/hr)	Exposure Rate (R/hr)	Kerma Rate (rad/hr)	H*(10) Rate (rem/hr)
Sm ^{60}Co	200	27.16	120	21.8	743.7	8.148E-01	1.0212	8.404E-01	8.398E-01	3.687E-03	3.237E-03	
	200	27.17	120	21.8	743.7	8.151E-01	1.0212	8.407E-01	8.401E-01	3.688E-03	3.238E-03	
	200	26.99	120	21.8	743.7	8.097E-01	1.0212	8.352E-01	8.346E-01	3.664E-03	3.216E-03	
	200	27.18	120	21.8	743.7	8.154E-01	1.0212	8.411E-01	8.405E-01	3.690E-03	3.239E-03	
	200	26.96	120	21.8	743.7	8.088E-01	1.0212	8.342E-01	8.336E-01	3.660E-03	3.213E-03	
									Average:	3.678E-03	3.229E-03	3.745E-03
									Std Dev :	1.461E-05	1.283E-05	
Sm ^{252}Cf	100	5.638	300	22.1	744.0	5.638E-03	1.0219	6.914E-02	6.854E-02	3.009E-04	2.641E-04	
	100	5.691	300	22.1	744.0	5.691E-03	1.0219	6.979E-02	6.919E-02	3.037E-04	2.667E-04	
	100	5.654	300	21.9	744.1	5.654E-03	1.0211	6.928E-02	6.868E-02	3.015E-04	2.647E-04	
	100	5.619	300	21.9	744.0	5.619E-03	1.0212	6.886E-02	6.826E-02	2.997E-04	2.631E-04	
	100	5.497	300	22.1	744.0	5.497E-03	1.0219	6.741E-02	6.681E-02	2.933E-04	2.575E-04	
									Average:	2.998E-04	2.632E-04	3.158E-04
									Std Dev :	3.935E-06	3.455E-06	
								Bkgd (nC/hr)				
							Average:	5.978E-04				
							Std Dev :	3.313E-04				

5. References

1. ICRP Publication 74. *Conversion Coefficients for use in Radiological Protection against External Radiation.* Pergamon Press, ISSN 0146-6453
2. Standard Imaging. *Energy Dependence of Exradin A6 Spherical Ion Chamber*. June 2008.
3. Standard Imaging. *A3/A4/A5/A6 Spherical Ionization Chambers User's Manual*. DOC #80360-03, Feb 2005.